DOI:
10.1080/19422539.2017.1360612

Document Version
Peer reviewed version

Christian Beliefs and Values in Science and Religious Education.

Paul Black

School of Education, King's College London, United Kingdom.

Teachers, both of science and of religion, have to help pupils to learn about the links between these subjects. An effective way to support this learning should start from the beliefs and ideas that pupils already have, ideas which might well be influenced by public debates, often characterised by controversy, between those holding strong beliefs about the two areas. This article aims to give teachers a framework of information and argument to guide their design of teaching in this overlap area. In the *first* of three main sections, there is a summary account of the history of the science-religion relationships, showing that over the last two millennia they have oscillated between positive support and negative controversy. A *second* section analyses this history in terms of three models of the relationship. One is a model of conflict in which each disputes the knowledge claims of the other. Another is one of mutual independence in which each accepts to work within its side of an agreed boundary. Finally, there is a model of collaboration, in which each discerns positive contributions that the other can make to its own insights. The *third* main section discusses the implications of the preceding analyses for curriculum and pedagogy in both science education and religious education, with a stress on the similarity between the pedagogic aims and values to which teachers of both subjects should work.

Keywords: science, religion, creation, scripture, atheism, geocentric, evolution, pedagogy.

Introduction.

The wide range of opinions about the relationship between science and religion may be discussed in terms of three, albeit overlapping, categories. The first stresses *Conflict*: some scientists say that religion has, in the past and even now in some spheres, tried to suppress or distort the work of scientists. Furthermore, science can now answer many of the questions which religion once sought to answer, so that it can now replace most of the insight and guidance that religion claimed to provide. In fact, it is claimed, science can at least prove that the concept of God as creator is no longer necessary, whilst some go further and claim that it can and will prove that God does not exist.

The second opinion is that the two fields differ from one another both in the questions that each tries to tackle and in the methods that each uses to meet its aims. *Separation* of the two is needed so that each can go its own way and ignore the work of the other.

This second approach avoids controversy but also misses the rich opportunities explored by the positive perspective of the third, which aims at *Partnership*. The emphasis here is that the findings of science can enhance our wonder and delight at the created universe, and so give more detail and substance to the long tradition of admiring God's creation – of the natural world which supports our lives, and of ourselves as creatures able to learn from that world. Thus, science can enhance our worship and our understanding, both of ourselves and of God's message to us through the scriptures.

These three approaches set the context within which educators have to design their teaching. The overall aim of this article is to equip teachers with a basis of understanding

and of resources which might enrich the design of their teaching. Teachers have to establish positive links between the religious and the scientific perspectives, and respond to problems which students are likely to encounter in a world where conflict between science and religion often attracts publicity. Indeed, the challenges that teachers both of science and of religion face is that the present socio-cultural climate is secular and unduly influenced by some atheist scientists, so that religious faith is seen by many as irrelevant and out-dated. School pupils, even in an avowedly Christian school, are bound to be influenced by this climate.

The arguments in this article are organized in four main sections as follows :

- A brief account of the history of the relationships between science and religion.
- A discussions of three possible relationships between science and religion
- Implications for classroom teaching.
- Conclusions overall.

Two of the sources on which I draw are recent articles in this journal, by Polkinghorne (2011) and by Consolmagno (2012). My presentation is less detailed than either Polkinghorne's in its discussions of the philosophies of science and of religion, or Consolmagno's discussion of theories of modern physics. It differs from these in giving more attention, both to the history of the oscillating relationship between the discoveries of scientists and the Catholic Church's teaching, and to the range of perspectives from which this relationship may now be viewed.

History of the relationships

Before and during the first few centuries of the Christian Church, there can be seen the beginnings of science, in work based on analysis of observations of nature. An early example was the work of the Venerable Bede, a monk who, in the first 35 years of the 8th century, was author of numerous books about the study of nature. His monastic curriculum included learning about nature, and he tried to compose a single system to inter-relate observations of the heavens, stars, and planets. He also studied the physical geography of the Earth: one problem he tackled was to explain why the sea is salty when freshwater rivers are continually flowing into it: using the evidence that fresh water is less dense than salt water, he proposed that it stays on the surface and returns to the mountains by evaporation and precipitation. Whilst other Christian writers were using moral and spiritual allegories to explain nature, he sought to explain nature solely in its own terms.

Another example was Grosseteste, a Franciscan monk who early in the 13th century tried to develop the understanding of nature by the interplay of observations and ideas. He wrote about many topics, noting in particular that light has a natural extension whereas matter does not. To explain creation he proposed that a flash of light might have spread, then solidified in an external shell and re-radiated back from its perfected matter to give a set of shells, leaving at the centre the un-perfected and changing elements of earth, air and water; a model which bears some comparison with our current Big Bang model. However, he was also a biblical scholar and both in this work and in his scientific work he was seeking to develop a unified view of these two disciplines.

Later in the same century, Albertus Magnus, a Dominican whom the Church canonized as the Patron of Natural Scientists, made his own extensive first-hand observations. He wrote about his studies of insects, zoology and astronomy, and about the ways in which some minerals are transformed when used in the manufacture of metals. He stated that "The aim of natural science is not simply to accept the statements of others, but to investigate the causes that are at work in nature". He also wanted to work towards a view in which all branches of knowledge were studied to achieve the synthesis of all our activities in the service of God.

Throughout the 1st to the 16th centuries, ideas derived from Aristotle's philosophy were dominant. This philosophy relied on the priority of reason, including the abstract reasoning of mathematics. It distinguished between our observations of a fact and the rational knowledge of the reasons for that fact – the latter having priority because the senses could mislead. From the Aristotelian perspective, the geocentric view was held as a view justified by reason. However, whilst the motion of the sun was perceived as circular, the observed motions of the planets were more complicated, a complication which was resolved, using the 2nd century work of Ptolemy, to produce a geometrical model in which each planet's motion was represented in terms of epicycles, each a superposition of one cyclical shape on another. The overall model was of the local system of the Earth and of its immediate environment, with their complex phenomena of motion and change – but with no attempts to propose underlying causes for such motions. Outside this system, from the moon and beyond, was a set of spheres the nature of which was seen to be consistent with the biblical accounts of creation, which were of ideal and unchanging shapes, and which were thought to be 'teeming with spirits' (Consolmagno, p.113).

A different, heliocentric, model was proposed by Copernicus in the first half of the 16th century (Copernicus, 1991). He dedicated his work to Pope Paul III and it did not raise alarm at the time. Philosophers dismissed it, whilst some scientists, notably the astronomer Tyco Brahe, disagreed with it. Church leaders respected Copernicus, as a Church ecclesiastic and as a scholar, but regarded his idea as an ingenious mathematical device which could not claim to represent the reality as described in Genesis.

Galileo, who worked between the latter half of the 16th and the first half of the17th centuries, came to accept the Copernican model, but this acceptance was transformed when he built one of the first effective telescopes and used it to make new observations. These revealed that there were more than seven planets, that at least one planet had moons moving around it, that our moon was not a perfect sphere but had irregularities on its surface which might be mountains, and that the sun itself was rotating on its own axis. When Galileo published these findings many in the Church became concerned because they might undermine Sacred Scripture. Galileo protested that he was only making models and not claiming that these were a true representation of reality.

When a new pope, Urban VIII, was elected, he discussed the draft of a book which Galileo wished to dedicate to him. After some consultations, Galileo was advised to alter the title and some of the comments in the draft, in particular making clear that his heliocentric idea should be seen as a hypothesis (see Poole, 1995, p.109), the pope was able to assure Galileo that he would not have to fear his enemies. Given this reassurance, an account of his astronomy work, entitled *Dialogue Concerning the Great World System,* was published in 1629. This book was a literary work, aimed to influence public opinion. It was welcomed by

the general readership, but there was debate in the Church over whether Galileo could be said to have committed heresy. Eventually, he had to appear before the Inquisition in April 1633. Two months later the inquisitors declared that the heliocentric view was false, philosophically absurd and heretical and that the proposition that the Earth was not immovable was also false. The condemnation document which he was asked to sign contained no hint that he was not a faithful Catholic. He then left Rome to settle in Florence and spent his last eight years in comfortable accommodation, but forbidden to either publish or to leave his approved home. However, his book, albeit formally prohibited, became widely available in Europe.

One of the several damaging consequences of this outcome was that it hardened the Church's commitment to the view that theology and philosophy should formulate the universal principles of all the sciences, so that it was inconceivable that science could challenge, or enrich by observation and argument, these superior disciplines.

Another damaging consequence was that it sought to undermine the arguments of a man who is now recognised as a distinguished scientist. For example, when Galileo saw that the moon's surface was irregular so that it might not be part of the unchanging heavenly firmament, or that some planets were like the earth in having their own 'moons' moving around them, he was establishing the claim that science was an independent source of knowledge which might serve to modify the interpretations of the Scriptures. At the same time, Galileo was also making important contributions to science by experimental studies of the physics of motion. However, he mistakenly dismissed the work of Kepler whose breakthrough in treating planetary orbits as ellipses rather than circles led him to establish new relationships between the orbit sizes and periods of all planets. Here, as elsewhere, it seems that Galileo was not content to tread cautiously in asserting his own insights, so that he offended many in a Church which was still coping, through its Counter- Reformation which spanned the 16th and 17th centuries, with assaults in which the interpretation of the Scriptures was a key issue (see DeSantillana, 1958 ; Catholic Encyclopedia).

The decrees of the inquisition did not suppress the progress of science, and its condemnation of the heliocentric theory slowly became irrelevant, although it was only formally retracted in 1992 by the Pontifical Academy of Sciences, who recognised that Galileo's emphasis on the need to distinguish between the Scriptural texts and their interpretation was fully justified.

Galileos's findings were, when combined with Kepler's, the main inputs basis for subsequent achievements of Newton. His outstanding contribution to physics was presented in his 1687 book entitled *Mathematical Principles of Natural Philosophy,* where he set out his laws of motion and his law of gravitation. However, Newton was also a theist who studied biblical prophecies: he tried to align a literal interpretation of Genesis with scientific theory.

About the same time, an Anglican clergyman, Thomas Burnet, attempted this same task of alignment, publishing in the 1680s his "Sacred Theory of the Earth". This was an ambitious task, and many of the explanations which he produced seem ridiculous by current standards: however, his stated motivation was that " 'Tis a dangerous thing to engage the authority of scripture in disputes about the natural world, in opposition to reason; lest time, which brings all things to light, should discover that to be evidently false which we

had made scripture assert" (quoted in Russell, 1985, p.133). He did have a friendly exchange with Newton, in which they argued about explanations of the '6 days of creation' stated in Genesis. Burnet's best explanation was that the term 'day' was used in an allegorical sense in the Old Testament.

New arguments developed in the growth of the studies of plants and animals. Systematic observations were published by Linnaeus in the *Systema Naturae*, which, in its 10th edition in 1758, classified 7,700 species of plants and 4,400 species of animals, including man. Some Christians objected to this because by putting man at the same level as monkeys or apes, it contradicted the Biblical message that man was created in the image of God. This conflict was the forerunner of the creation-evolution controversy which began in earnest when, in 1859, Darwin published "On the Origin of Species". His theory of natural selection implied that new species emerged, from amongst random variations, of those best equipped to survive. He retained a belief in the existence of a creator, but thought that understanding the nature of God was beyond our intellect – indeed that 'A dog might as well speculate on the mind of Newton' (Gould, 2002 p.36).

There followed in 1860 a meeting of the British Association for the Advancement of Science in which doubts about Darwin's book, expressed mainly by scientists, were discussed (Poole, 1995). One of the participants, the Bishop of Oxford, William Wilberforce, in a review of the book, said that "we have objected to the views with which we are dealing solely on scientific grounds" and pointed out several weaknesses in its scientific arguments. However Huxley engaged in the debate to pursue a wider purpose, one which was prompted by two different ways of thinking which converged at this time.

The first was a reaction to a heightened appreciation of the wonders of the natural world, a romantic view of nature expressed in the poetry of (for example) Wordsworth. Russell (1985, chapter 9) describes this as 'deism '– worship of a god who inheres in nature rather than transcends it: such belief was bound to conflict with the scientists' attempts to explain that natural world in terms of universal laws of nature.

The second was the mission of a group of scientists, led by Huxley, to establish that science had a claim to attention and status wholly independent of established religion and not needing legitimation from the church.

The Catholic Church does not appear to have made specific statements about evolution prior to the 1950 statement of Pius XII, in the encyclical *Humani Generis,* in which he said it was acceptable, but that the polygenism was not acceptable for, as the scripture made clear, all man descended only from Adam, so that all were subject to original sin. A later statement, by John Paul II in 1996, was more welcoming, recognizing that the theory was now well-established. He also addressed the discontinuity between the two origins, of body and of soul, arguing that whilst the transition to the spiritual cannot be a subject of scientific investigation, such investigation can discover some valuable signs, notably of self-consciousness, awareness of freewill and of religious experience, which are specific to the human being.

There were no new challenges to acceptance of the work of scientists, as an independent contribution to our understanding of the natural world, until the work of physicists in the 20th century opened up new possibilities. Their new theories led to speculations about the

beginning of the whole of creation (see e.g. section 19 in Whittaker, 1949). As astronomy expanded to cover a wide range of electromagnetic radiations well beyond the visible spectrum, it became clear that, overall, the distant galaxies were moving away from us. This evidence of universal expansion raised the question of its origin, leading to the theory that matter had started in a highly compressed state and had then blown apart in the Big Bang. Hawking (1988) describes a conference about this topic held at the Vatican Observatory in 1981.-Pope John Paul II, attending a closing session, welcomed the scientists, but said that "it was alright to study the evolution of the universe after the big bang, but we should not inquire into the Big Bang itself because that was the moment of Creation and therefore the work of God " (p.131): Hawking had just given a talk on a study of his which was doing just that, and there is now a rich variety of speculations about this issue. One of these proposes that there was a pre-existing space devoid of matter in which fluctuations in the fields of gravity and electromagnetism might have triggered the creation of matter from energy which led to the Big Bang.

Three categories of the relationships between science and religion

Prologue

This section presents a survey of the many and varied aspects of the relationships between science and religion in terms of three broad, albeit overlapping categories, namely *conflict*, *separation* and *partnership*. However, there are two issues which occur throughout this survey and it is helpful to discuss these first as a prologue to the survey.

The first concerns the philosophic arguments about the existence of God and the concepts of Creation and of a Creator. The idea that the universe -was created by God is not an alternative to the scientist's explanation of the universe. It is an answer to a question that science cannot answer, which is why this universe exists at all, rather than nothing. Science cannot explain how it emerged from nothing, for 'nothing' has no properties that are either measurable or related to entities to which the theories of science apply. As Wittengstein explained in his Tractatus (1922): *Not **how** the world is but **that** it is the mystery*. To understand the full implication of this view, it is important to be clear about the meaning of the term 'Creator'. A carpenter might say that he 'created' a chair, but the chair would only stay in existence after he had finished because of his use of materials – wood, screws and so on – which do not depend on him for their existence. By contrast, *all* the properties of the universe depend on its Creator for their existence: if He were to cease to hold them in being they would cease to exist, for there would be nothing about them which does not depend on Him. Consolmagno sums up, and takes further, this argument in saying *"God is the reason why existence itself exists"* (2012, p.120).

However, there is more involved. The Creator of the universe would have to be outside its framework, of space, time and matter, entities which He created. The question "Where is God?" cannot have an answer in the language that we use to discuss 'where'. A similar difficulty applies the question "What was God doing before He created our universe?" That question makes no sense because, as the Creator of our time, He cannot be measured as if He were located within that time.

The second concerns Revelation and the Church's interpretation of the scriptures. The history, briefly outlined above, may be seen as one of continual retreat. The Church has repeatedly placed limits on, or rejections of, the observations and theories of science,

declaring that because they contradict divine revelation they must be false. Such assertions have subsequently lost impact and in some cases have been formally withdrawn. These negative phases have been interleaved by periods when Church leaders have welcomed the work of scientists, some being scientists themselves. As I shall argue below, such changes should not be seen as an abandonment of, or retreat from, our core Christian beliefs . To quote Consolmagno again

> *"I would argue that all these religions (certainly it is true of Christianity) are strengthened by experiencing a shift in our assumptions. That's where we find out what's essential and what is cultural baggage."* (p.119)

Conflict

The best known conflict can be seen in the active propaganda of a group known as the New Atheists, led by the evolutionist, Richard Dawkins, in his 2006 book *The God Delusion*,. This group claims that science has proved that the universe cannot have had an outside creator, and they combine this with evidence that religion has done a great deal of harm to humanity. Two of the five leading members of this group, Dawkins (2006) and Krauss (2012), are scientists, the others (Dennett, Harris and Hitchens) are not. The arguments of Dawkins have been analysed by McGrath and McGrath (2007): they expose the logical weakness of several of the claims that Dawkins makes, his lack of understanding either of the philosophy of science or of theology, and the many inconsistencies between his various arguments. One of these claims, that most scientists are atheists, simply contradicts the available evidence. Dawkins also belittles statements by scientists with whom he disagrees, saying, for example, of the distinguished evolutionist Gould, that "I simply cannot believe that Gould could possibly have meant much of what he wrote in *Rocks of Ages* " (quoted in Aczel, p.198).

The converse of this type of conflict is the position adopted by those Christians who insist that if science appears to contradict their literal interpretations of the scriptures it must be wrong. To justify their position, they adopt one of the wide variety of types of 'creationism' (Poole: 1995, 2008). For example, some assert that the human race started with the creation of Adam and Eve, others that the universe was created in six days, others that the Old Testament shows that it was created between 10,000 and 6,000 years ago, and others that a Creator could have designed the world so that it looked as if it had been created over geological time. Warfare grounded in creationist views has damaged school science education, notably in the USA states of Tennessee, Louisiana and Arkansas, where, from the 1920s, the teaching of evolution was forbidden until, after a long battle, the US Supreme Court ruled, in 1987, that such laws were unconstitutional. Gould (2002, ch.6) gives a detailed account of this battle, pointing out that the study of evolution is still limited in some districts because teachers wish to avoid controversy with their local creationists. A 2014 Gallup poll found that 42% of Americans believed in creationism rather than evolution (THE, 2016)

A different critique of evolutionary theory is the theory of Intelligent Design. Its proponents claim that some of the findings about nature show evidence of a complexity that cannot be explained solely in terms of natural processes. The implication is that these are evidence of the direct action of a creator, so that the possible scope of the work of scientists must be

limited. Polkinghorne (2011) pointed out several weaknesses in this view. One is that it is undermined by evolutionary theory because:

> *" . .Charles Darwin when he showed that the patient accumulation and shifting of small differences could, over many generations, bring about the appearance of design without calling for the direct intervention of a divine Designer" (p.140)*

He identified a second and more fundamental objection – that it was difficult to argue in favour of a personal God who first set up his creation of the world, then chose at a later stage to intervene – thereby violating the laws of his own creation.

Separation

Such attacks, whether on the beliefs of Christians or on the truth claims of scientists, are not common amongst scientists. What is more common is the *separation* view. This view is adopted by scientists who wish to respect those with religious belief whilst not wanting to take seriously any claim of religion to contribute to our understanding of reality. In so doing, they give indirect support to the effect of present cultural conditions, which actively work against religious faith (Groome 2011, p.3).

Some however make their view of *separation* more explicit. One declared agnostic, Amir Aczel, a science writer and a mathematician, has pointed out, in his book entitled *Why Science Does Not Disprove God* (2014), that, in pursuing their purpose of disproving the existence of God, the New Atheists distort science and, in consequence, their arguments are often tendentious, thereby compromising science. Thus the declared purpose of Aczel's book is to "defend the integrity of science": however, whilst he does not support either of the above types of *conflict*, he also expresses his own *separation* view.

Aczel's arguments draw on accounts of the origins of science, pointing out that developments in archaeology have, as time goes on, uncovered more documentary evidence that is consistent with the biblical narrative, thereby contradicting the claim by Hitchens that modern archaeology has disproved biblical history. He also points out that the leading figures in the growth of science from the 15th to the 18th centuries were all religious believers, and that the Big Bang theory was first proposed, in 1927, by a Jesuit, Georges Lemaitre. Aczel's detailed account of modern cosmology also contradicts the claim by Krauss that quantum theory shows that something can appear out of nothing. That claim was based on the hypothesis that matter first arose from interactions, in a space devoid of matter, between fluctuating gravitational and electromagnetic fields. This claim is illogical because that pre-existing space cannot be said to be 'nothing' – it was an existing entity and cosmologists are still arguing over the physical properties of that entity. Positive elements of Aczel's beliefs are set out in two chapters, one entitled *Art, Symbolic Thinking, and the Invisible Bo*undary, and the other *Engaging the Infinite*, wherein he argues that spirituality, religion and faith have an important part to play in our lives and that both science and spirituality are 'integral parts of the human search for truth and meaning". Thus he is prepared to search for ideas that transcend the *separation* boundary.

Another exposition of the *separation* view was published by Gould, an eminent professor of zoology and geology, in his 2001 book, the subtitle of which, *Science and Religion in the Fullness of Life,* specifies the dual agenda of the work. He again wrote as an agnostic. His emphasis on separation was more explicit than that of Aczel, but was similar in that he gave

a detailed history of the growth of science and of the oscillating links between the beliefs of Christians and the institutions of Christianity. The book's theme is summed up by the acronym NOMA – the Non Overlapping Magisteria of science and religion: he defines 'Magisterium' as 'a domain where one form of teaching holds the appropriate tools for meaningful discourse and resolution' (p.5). His view is that both science and religion often have overlapping subjects of inquiry, but that science cannot use its knowledge of the world's empirical constitution to claim higher insight into moral truth. The first of his three main principles is that nature cannot tell us about the nature of God. The second is that, whilst we like to look at the appealing aspects of nature, we have to accept that it can be ugly and, given such examples as infectious diseases or predatory animals, also very cruel. Hence his third principle is that nature doesn't care about us and that therefore science, as such, cannot provide advice on overarching purposes and ultimate values – we have to take the hardest of all journeys on our own. However, Gould has also pointed out that 'Either half my colleagues are enormously stupid, or else the science of Darwinism is fully compatible with conventional religious beliefs – and equally compatible with atheism' (quoted by McGrath & McGrath p.13).

However, Gould also made a plea for *irenics,* i.e. for a peaceful relationship, but. that scientists should avoid the tendency to take a 'soft' and fuzzy line in an uncritical acceptance of points of possible unification, for example in saying that the Big Bang accords with the Genesis account of creation.

Partnership

The third option for the relationship is that of *partnership*. As shown above, some who choose the option of *separation* do not rule out some degree of *partnership*. However, a stronger metaphor for this third option may be marriage, for this implies a declared commitment to mutual support.

One approach, which may be seen as a tentative contribution to partnership, is provided by arguments which focus on the Anthropic Principle, a detailed account of which is given in chapter 5 of Poole (1995). The basic theme here is that science has shown that the universe is 'just right' for providing the conditions for the evolution of humanity. This theme can draw on many examples. In cosmology, it can be shown that the conditions which humans enjoy on the surface of the Earth require a star at just the right stage in its evolution, a planet which is not too close to, yet not too distant from, such a star, with a composition and a history that can lead to the combinations of land and water which are required for the evolution of life. A more fundamental finding emerges from the theories of physics about the relative sizes of the charges of the electrons, protons and other particles and the sizes of the entities that determine their interactions. These sizes appear to be very finely tuned, such that a tiny difference in any one them would have made impossible the existence, of matter as we know it and therefore of ourselves. The chances that these fine tunings occurred at random are unbelievably small, so the universe must have been designed to make our existence possible. However, some have argued that ours may not be only universe in existence, and that it is one amongst the numerous parallel, but all slightly different, universes which actually exist. Polkinghorne comments on this reaction as follows :

> *" Anthropic fine tuning came as a shock to many scientists. They prefer the general to the particular and so they were inclined to suppose that there was nothing very*

> *special about out universe. Natural Theology understands anthropic potentiality to be the gift of the Creator to creation"* (p.142)

A partnership relationship can only be fruitful if both partners are aware of their own limitations. For example, the 'laws of science' arise from the legitimate aim of scientists, which is to achieve objectivity. Insofar as they relate to observations of the natural world, any scientist can repeat and check the claimed observations. However, the claims about them, implied by calling them 'laws', usually extend well beyond the limited range of observations which supported them: examples from past history are the law of conservation of energy and Newton's laws on motion. Whilst limitations in both of these have been exposed by current physics, they had been powerful and productive precisely because, although they implied claims beyond the limitations of existing data, they thereby provoked new observations. Thus, there is a complex interplay between abstract theories, and concrete experimental results which depend on these theories for their origin and for their interpretation. Consolmagno (2012: pp. 112-116) describes many examples of this interplay in the historical development of cosmological physics.

The basic limitation here is that all other factors which might affect any observations have to be the same when repetition is attempted, and awareness of relevant factors will be constrained by existing theories. Indeed, it is often evident that what scientists' sophisticated apparatus is actually measuring can only be understood by reference to the theory on which interpretation of its results is based.

Different types of limitation arise in those areas of science where is little scope for experimental work to help test new generalisations. Examples are the geologists' studies of the Earth's rocks, the biologists' studies of fossils, and the physicists' studies of motion at speeds approaching the speed of light. Polkinghorne (2011, pp138) develops this point in his more fundamental analysis of the philosophy of science, drawing on Polanyi's 1958 book entitled *Personal Knowledge*. He explains that the practice of science requires tacit skills of judgment and that the 'skills' and understandings of scientists can only be acquired through apprenticeship into the science community.

Just as the scientific partner in this relationship has to be aware of the limitations of science, a similar caution is also need from the religious partner. One example, which may at first sight be seen as unhelpful, is the fact that Christians have frequently used a 'God of the gaps' argument, i.e. invoking the Creator's direct action to explain some phenomena that have baffled scientists. As science has been able to explain these phenomena, the 'gaps' have disappeared and retreats by Christians have followed, so supporters of *conflict* then claim that the traditional faiths are grounded in myths which science is steadily undermining. There is however a positive interpretation here, based on the belief that our understanding of the Scriptures, and of Christian doctrine which interprets them, has been developing over time as advances in human knowledge and changes in human culture, have refined and deepened that understanding. Thus the filling of the 'gaps' by science has developed our understanding of the scriptures.

In the gospels there are numerous passages where Jesus is explaining that the Jewish leadership's interpretations of the Old Testament were wrong, and in one of His final messages to the disciples He said:

> *"I still have many things to say to you but they would be too much for you to bear now. However, when that the Spirit of truth comes, he will lead you to the complete truth, since he will not be speaking of his own accord, but will say only what he has been told; and he will reveal to you the things to come."* (John ch.16:12-13).

In this view, we can, through science, come to know something about God through his *works,* and wonder at the fact that we are able to take delight in them. However it can only give us a limited understanding of the Creator: to go further we have to rely on God's *words* (Black et al., 2007). Apparent conflicts between the two may serve to challenge and refine our understanding – of one or the other, or of both.

A similar theme was expressed in one of the Documents of Vatican 2 (1966), entitled *Gaudium et Spes*: Chapter III on *Man's activity throughout the world,* which was explicit in deploring those who

> *do not sufficiently attend to the rightful independence of science*

but then struck a more positive note stating

> *when a man applies himself to the various disciplines . . he can do very much to elevate the human family to a more sublime understanding of truth, goodness and beauty.* (p.234)

A similar positive view of a potential partnership relationship was expressed by Kepler, asserting that the work of scientists was part of God's intentions:

> *Those laws are within the grasp of the human mind: God wanted us to recognize them by creating us after his own image so that we could share in his own thoughts* (quoted in Crombie 1957, p.188)

An example of the search for a strongly positive relationship has been presented by the Jesuit theologian, Mahoney (2011), drawing on the firm evidence in support of the theory of evolution. Put briefly, he suggests that the argument that the 'facts', of Adam, Eve and the Fall, made necessary the Incarnation and Christ's act of redemption, is inadequate. It implies that God had a plan A, which was undermined by humanity's preference for pride and disobedience, so He had to implement plan B. Mahoney suggests a quite different perspective, in which the creation plan included the process of evolution with humanity as the end-point of the design. In human history one can trace the evolution of moral sense, of altruism and of reflective and spiritual thinking. However, the ultimate step in such development was for our human life to be incorporated into the life of the Creator, a step beyond the scope of natural evolution. The Incarnation and the Redemption, the complete sharing of the Son with our humanity and the subsequent descent of the Spirit, bridged this gap. These events were the final completion of the process of evolution, an essential and integral part of a single plan, designed to enable humanity to take the ultimate step into participation in the Divine life.

This simplified précis risks bowdlerizing a serious and scholarly work which draws on the work of theologians, from Augustine and Aquinas to Kung and Rahner. I include it here to draw attention to the problem that Mahoney was trying to tackle, one that was presented in the following terms by Pope John Paul II :

> *"Does an evolutionary perspective bring any light to bear on theological anthropology, the meaning of the human person as imago Dei, the problem of Christology – and even upon the development of doctrine itself?"* (quoted by Mahoney p.18).

The above examples of a positive relationship can be summed up in a principle – that both science and religion are equally necessary for an adequate account by each of their fields of inquiry, so that there must be exchanges of insights between them. It follows that their relationship should be seen as complementary rather than as a rivalry, for in the search of each of them for truth they have many things to say to one another. This principle was expressed in Polkinghorne's detailed exploration of the link between the two:

> *This understanding leads to the picture of creation as a continuously unfolding process in which God acts as much through the results of natural process as in any other way. A fruitful dialogue between science and religion has to be based on this understanding of creation.* p.142

Finally, an additional perspective on the positive relationship is presented by McLeish in his book entitled *Faith and Wisdom in Science* (2014). He argues, as an experimental scientist, that both science and theology have to be universal so that no problem or insight can belong to one and not to the other. One example which he explores is that studies of human consciousness can enrich the understanding of meditative prayer.

Many scientists have written about their experience of delight when they have been the first to discover one more property of God's creation. McLeish links such delight to the Wisdom books, starting with a quote from Proverbs (8.30):

> *I was beside the master craftsman*
> *Delighting him day after day,*
> *Ever at play in his presence*

He explores this theme in more detail by devoting a whole chapter to the Book of Job. Responding to Job's complaints about his perception of the lack of order in the world, Yahweh explains that Job should be able to overcome his lack of understanding through a deeper encounter with Wisdom, thereby looking to a future when man's inadequate relationship with the natural world can be enriched.

It is significant that an important part of McLeish's study is an account of the development of scientific inquiry, from before and during the early mediaeval times (as is done in my first main section above). His overall view is that the harmony between religious belief and scientific inquiry was fractured during the later Middle Ages but can now be rebuilt, a harmony in which our understanding of both fields, and of the claims of each, are now built on a firmer basis.

Implications for classroom teaching

The religious faith and purpose of any school must be realised in all of its teaching. This is a particular challenge because the curricular subjects cannot be treated as mere adjuncts to faith: teachers have to forge a synthesis between their faith and the culture of each school subject (McKinney, 2011).

The central role of the teacher was pointed out by the Benedictine headmaster of a Catholic school, Dominic Milroy (1992) :

> *(Parents) know that, for the child, the encounter with the teacher is the first major step into outside society, the beginning of a long journey towards adulthood in which the role of the teacher is going to be decisive.* p.57

A related perspective was emphasized by Groome (2005) as follows:

> *Educators can take over functions that learners should be doing – learning how to learn, making up their own minds, reaching personal decisions. Such imbalance ill serves learners and can be destructive to educators. There is a fine line between empowering learners as their own people and overpowering them– making them too dependent or indebted to teacher or parent. Walking this tightrope is an aspect of the educator's spiritual discipline of a balanced life.* p.348

In classroom teaching, there is a spectrum between two types of interactive discourse – the delivery style and the dialogue style. In the former, the teacher tells learners what they are supposed to know and assessment involves testing to check that knowledge. In the latter the teacher involves learners in expressing their pre-existing knowledge and understanding of the topic, and then challenges this with activities and evidence so chosen that, through their active involvement with these, learners will transform their ideas: assessment then involves frequent informal checking to modify the activities so that they match, and build on, the learners' progress. In science education, a dialogue style is essential for science itself lives and develops through active and critical inquiry, so that to pretend that it is mainly a set of established truths is to give pupils misleading guidance when they come to choose for or against further study of science. A detailed account of these issues is given in Black (2014).

The need for careful attention to dialogue involves both oral dialogue and dialogue in other forms, and here the quality of the feedback is crucial. The research findings of Butler (1988) and of Dweck (2000) show that the choice between feedback on written work given as marks, and feedback given only as comments, can make a profound difference to the way in which students view themselves as learners: confidence and independence in learning is best developed by the second choice, i.e. by feedback which gives advice for improvement, and avoids judgment. Learners must believe that success is due to internal factors that they can change, and not due to factors outside their control, such as an innate ability or being liked by the teacher. Teachers who believe in the value of competition ought to note that every competition stigmatizes losers as well as rewarding winners.

The development in science teaching of the approaches and skills of 'scientific inquiry' has been a key priority for national policies in recent years: for example, the European Commission (2007) has given it high priority. In such work, students observe phenomena and the find ways to explain them and to test their explanations by experiment and/or by further observations, thereby, with careful teacher guidance, developing an authentic understanding of what is involved in 'doing science' (Harrison, 2014). In addition, there can be a broader benefit, for it is also thought that an inquiry approach provides both the impetus and experience that helps students acquire problem solving and lifelong learning skills. In such work, students develop the habit of participation in a reasoning discourse.

Many young students may have no experience of participation – in their home, or in the street, or in the playground – in reasoned discourse. The school may well be the only place in which they can experience such discourse, and come to participate in it.

Whilst it is beyond the scope of this article to discuss parallels between the above and religious education, a brief extract from the 2011 text of Groome will serve to highlight how the aims and methods have a great deal in common. He grounded his work in the Gospels, stating, for example, that:

> *"Jesus's approach has tremendous respect for the learners. His whole interest was to empower people to become agents of their faith rather than dependents. He was not looking for docile devotees, as a cult leader might do."* p.31

As part of this approach, Groome emphasises that any teaching should start by inviting learners to think about their own experiences, encouraging them by reflection and by His teaching, to discern deeper implications, with emphasis throughout on building a community with Him. The similarity here between the arguments for enriching science education is striking – but it should not be surprising.

Conclusion overall

This article does not aim to provide an ideal curriculum design to which teachers may work. This cannot be done because curriculum design in any one school may have to work within constraints externally imposed by district or national authorities, with further constraints arising from expectations both of the school's own governance and of the parental community. Furthermore, beliefs and backgrounds may differ between those who teach the two subjects. It is not possible to design, from outside, a teaching plan which matches the expertise and beliefs of the community of teachers in any one school.

The resources and ideas in this article will have to be considered by each teacher who will have to transform and shape them to match his or her own context. A rich resource will be the experiences of other teachers in the same or very similar schools, particularly if a group of teachers can work to together to discuss and refine their experiences as they try to develop their teaching, so forming a community of practice. However, it is essential that the areas of overlap between the teaching of religion and the teaching of science should be discussed on a regular basis, both at the level of curriculum design and of week-to-week implementation of that design. This article will have met its aim if it provides resources which can help to give such discussions a sound basis.

Above text; 7923 words

Acknowledgement
The author is grateful to his colleague Michael Poole for his comments on an earlier draft of this article.

Disclosure statement
No potential conflict of interest was reported by the author

Notes on contributor

Paul Black is Emeritus Professor of Science Education at King's College London. His main academic work has been on curriculum and assessment in science education. In the 1990s he was chair of the School Education Commission of the Archdiocese of Southwark.

References

Aczel, A,D. (2014) *Why Science Does not Disprove God.* New York NY: Harper Collins.

Black, P., Poole, M. and Grace, G. (2007) *Science Education and the Christian Teacher*. London : Institute of Education.

Black, P. (2014) Classroom Practice in a Faith-Based School: A Tale of Two Levels. Chapter 29 pp.501- 514 in Chapman, J.D., McNamara, S., Reiss, M. J. and Wahid, Y. (eds) in *The International Handbook of Learning, Teaching and Leadership in Faith Based Schools* Dordrecht, Netherlands: Springer

Butler, R. (1988). Enhancing and undermining intrinsic motivation; the effects of task-involving and ego-involving evaluation on interest and performance. *British Journal of Educational Psychology, 58*(1), 1-14.

Catholic Encyclopedia. Available on-line at : http://www.catholic.org/encyclopedia/view.php?id=4949

Consolmagno, G. (2012) The new physics and the old meatphysics: an essay for the use of Christian teachers. *International Studies in Catholic Education.* 4(2) 111-121.

Copernicus (1991) *ON THE REVOLUTIONS ; BOOK ONE* (1991) Torun, Poland: Nicolaus Copernicus University Press.

Crombie, A.C. (1957) *Augustine to Galileo: Science in the Middle Ages 5th to 13th Centuries Vol.1* and *Science in the later Middle Ages & Early Modern Times 13th to 1th Centuries Vol.2* .London: Heinemann.

Dawkins, R. (2006) *The God Delusion.* New York: Houghton Mifflin Harcourt.

De Santillana, G. (1958) *The Crime of Galileo* . London : Heinemann

Documents of Vatican II. (1966) Abbott, W.M. (ed.) Dublin: Geoffrey Chapman

Dweck, C. S. (2000). *Self-theories: their role in motivation, personality and development*. Philadelphia, PA: Psychology Press.

European Commission (2017) *Science education now. A renewed pedagogy for the future of Europe* Brussels: European Commission. Retrievable from: http://ec.europe.eu/research/science-society/document_library/pdf_06/report-rocard-on-science-education_en.pdf

Groome, T. H. (2005) *Educating for Life.* New York: Crossroad.

Groome, T. H. (2011) *Will there be faith?* Dublin: Veritas.

Gould, S.J. (2001) *Rocks of Ages: Science and Religion in the Fullnesss of Life*. London U.K.: Jonathan Cape

Harrison, C. (2014) Assessment of Inquiry Skills in the SAILS project. *Science Education International.* 24(1) 112-122.

Hawking, S. (1988) *A Brief History of Time: From the Big Bang to Black Holes.* London UK: Bantam Books.

Krauss, L. (2012) *A Universe from Nothing: Why There is Something Rather Than Nothing*. New York: Free Press

Mahoney, J. (2011) *Christianity in Evolution: An Exploration.* Washington DC : Georgetown University Press

McKinney, S. (2011) A Rationale for Catholic Schools. Ch.9 in Franchi, L. and McKinney, S. (eds.) *A Companion to Catholic Education.* Leominster, UK: Gracewing

Milroy, D. (1992) Teaching and Learning: what a child expects from a good teacher. Chapter 10 in *Education: Putting the record straight.* Stafford UK: Network Educational Press.
McGrath, A. and McGrath, J.C. (2007) *The Dawkin's Delusion* London : S.P.C.K.
McLeish, T. (2014) *Faith and Wisdom in Science*. Oxford: O.U.P.
Polkinghorne, J.(2011) The incompleteness of science: reflections for Christian teachers and for others interested in the science-religion relationship. *International Studies in Catholic Education.* 3(2) 136-144.
Poole, M. (1995) *Beliefs and Values on Science Education.* Buckingham UK: Open University Press
Poole,M.(2008) Creationism, intelligent design and science education. *School Science Review.* 90(330) 123-129.
Russell, C.A. (1985) *Cross-currents: Interactions Between Science and Faith*. London: Christian Impact.
THE (2016): Times Higher Education, no.2264, July 2016, p.45. See also http://www.gallup.com
Whittaker, E. (1949) From Euclid to Eddington. London UK: Cambridge University Press.
Wittgenstein, L, (1922) *Tractatus Logico-Philosophicus* English translation London UK: Kegan Paul Ch.6 , p. 44
All quotations from Scripture use The New Jerusalem Bible, Reader's Edition 1990.

8547 of which 624 are the reference/footnote list